

MINUTES OF THE SIXTH MEETING

ELECTROCHEMICAL POWER SOURCE

R&D ADVISORY COMMITTEE

HELD

25 NOVEMBER 1993

NATIONAL DEFENCE HEADQUARTERS, OTTAWA

MINUTES OF THE SIXTH MEETING
ELECTROCHEMICAL POWER SOURCES
R&D ADVISORY COMMITTEE
25 NOV 1993
CONSTITUTION BLDG., OTTAWA

3734A-2 (DRDA 8)

20 April 1994

Chairman: Dr. G. Verville, DRDA 8, 996-4174
Secretary: Dr. E. Andrukaitis, DRDA 8-4, 564-7656

In Attendance:

Dr. G. Verville	DRDA 8	996-4174
Dr. R.F. Mann	RMC	541-6055
Mr. S. Eng	DVEM 5-4	997-9608
Mr. C. Brochu	DREO	998-2038
Mr. G.A. Morley	DIUP 7	995-8438
Mr. M. Goveia	QETE 4-2-2	994-0861
Mr. W. Fraser	DCIEM	635-2064
Ms. A.M. Sibbald	DACME 5-5-3	994-9630
Maj. J.D. Crawford	DLR 4-6	945-7683
Maj. C.S. King	DAS Eng 2-3	993-1509
Capt. R.A.E. Ross	DSIGs EM 2-3-2	995-7794
Mr. P. L'Italien	DVEM 5-4-3-2	997-5967
Mr. D. Pratt	DVEM 5-4-3	997-0382
Maj. R.W. Smith	J3 NBC 2-5	996-0007
Maj. D.J. Jardine	DCEM 4/PM HADCSII	943-6035
Capt S. Fortier	DSRO 3-2-5	997-4687
Lt. M. Fontaine	DSRO 3-2-3	??
Mr. R.A. Stephaniuk	DMAEM 4-3-4	991-9842
Lt. B.H. Boehm	DMAEM 4-3-4-2	991-9837
Capt. M.G. Black	DASP 2-4-4	998-1252
Dr. G. Donaldson	DRDA 8-3	564-7658
Mr. R.W. Nolan	DRDA 8-3-2	564-6854
Dr. E. Andrukaitis	DRDA 8-4	564-7656
Maj. J.J. Langen	PMO TCCCS/SR Rad Eng	996-4282
MWO J.P.L. Lebrun	PMO TCCCS	995-4862
Mr. J. Normandin	DPSCE 3-2-2	996-5851
Mr. M. Slack	DDIR 6	945-7107
LCol L.L. Hellemans	DRDL 6	995-2177
Mr. B. Laidley	DMEE 6-6-2	997-9385
LCDR R.A. Wall	DRDM 7	995-8338

Item	Discussion	Action By
	<u>INTRODUCTION</u> 1. The sixth meeting of the Electrochemical Power Sources R & D Advisory Committee was held in Ottawa at the Constitution Building, 305 Rideau Street, in the CRAD Conference Room at 0900 hours on the 25th of November 1993. Dr. Verville (DRDA 8) welcomed the attendees and introduced the agenda for the meeting. Brief introductions by all the attendees were made and the minutes of the previous meeting in Mar 93 was provided for general interest. Also provided were copies of two technical memos prepared by DRDA 8-3 and DRDA 8-3-2 for anyone interested in information dealing with lithium battery disposal and mercury-free alkaline batteries. It was noted that the last meeting was held in Mar 93 and that the next meeting would be held sometime in Nov 94. 2. The agenda for the meeting had been previously distributed and is included at Annex A. 3. <u>REVIEW of PAST MINUTES</u> The last meeting was held on March 24, 1993. Action items from the minutes of that meeting were noted: a. The action item of using CAM batteries (pg. 15/18, para 13 of the minutes of 5th meeting) which were in stock, for other equipment was not actioned by DSVEM 3-4 (who has since retired) or DSVEM 3. Power sources for the application in question were bought and the issue was passed to DSVEM. DRDA 8-3 stated that no further communication had ensued with DCGEM or DSVEM, but that the CAM batteries had been shown to be airworthy and that the responsibility had been handed over to DSVEM as the lead LCMM for batteries. The item was deemed closed by DRDA 8.	

Item	Discussion	Action By
	b. The action item regarding the writing of a memo on the problem with the lead-acid battery in submarines was sent by DMEE 6-6-3 to DRDA 8. It was determined that the problem mentioned in the memo was not of any risk to the CF at the moment and this item was deemed closed by DRDA 8. c. In regard to the DCIEM fuel-cell project, the fuel-cell technology information was mailed to DCIEM by DRDA 8. A contract was awarded in the summer of 93 to the University of Toronto (Lacec). The contract (\$500K) call for the development of a 5 kg man-portable power supply for the Integrated Protective Clothing Programme. d. <u>Comments:</u> DRDA 8 stated that the DCIEM project was of interest to other CF groups and hoped to have a presentation on the project at the next advisory committee meeting. 4. <u>OVERVIEW of DND ELECTROCHEMICAL POWER SOURCES R&D PROGRAMME (DRDA 8)</u> a. DRDA 8 briefly reviewed the history and internal structure of the DRDA battery programme and its interaction with the Land, Air and Navy elements. In the latest CRAD strategic planning process, power sources technology has been identified as a critical component of five CRAD technologies and two defence capabilities. b. The DRDA programme is meeting its objectives and a significant increase has been noted in the number of requests for technical assistance and advice. c. A summary of the DRDA 8 presentation is included at Annex B.	Mr. W. Fraser

Item	Discussion	Action By
	5. <u>CANADA-U.S. BATTERY SECTOR STUDY (DDIR 6)</u> a. DDIR 6 briefly reviewed the joint battery sector study. DoD/DND identified over 30 critical sectors of the North American Defence Industrial Base and the battery sector was selected. A battery working group was established with representatives from various DND and DoD — representatives to assess the health of the battery industry. b. The objective was to conduct an industrial base assessment of the North American battery industry and to recommend a cost-effective strategy for meeting future military battery needs. This would be accomplished by surveying the entire battery base and identifying critical battery chemistries. Key contractors would be selected for further study to obtain industry input. c. Adm Mat. is supplying funding for this study in the amount of \$30K U.S. of the total of \$125K U.S. The final report will include recommendations and the overall health of the battery sector. d. Briefings of the study will be made available for all those in attendance who wish an update. Another presentation of the final report will be provided at the next advisory meeting in Nov 94. e. A summary of the DDIR 6 presentation is included at Annex C.	DDIR 6

Item	Discussion	Action By
	6. <u>PRIMARY OR RECHARGEABLE BATTERIES U.S. MARINE CORPS COST ESTIMATE ON SINCGARS GROUND AND AIRBORNE RADIO SYSTEMS (DRDA 8-4)</u> a. DRDA 8-4 presented a report prepared last year for the United States Marine Corps SINCGARS project by the company, Management Consulting and Research, Inc. The report examined cost estimates of three batteries, the BA-5590/U Lithium sulphur dioxide, the BB-490/U Sealed lead acid and the BB-590/U Nickel-Cadmium battery. The SINCGARS project office estimated that about 56% (\$185 million) of O&S budget is for the procurement of the disposable batteries for radios and wanted to determine if money could be saved by using rechargeable batteries and anticipate the adoption of the Department of Defense Directive (DODD) 500.4 (making disposal of batteries an important issue). b. The study estimated the total annual cost per operational hour is \$2.66 for LiSO_2, \$0.34 for NiCad, and \$0.30 for lead-acid. They concluded that rechargeable batteries were cheaper to operate with Pb-acid slightly preferable to NiCad batteries for SINCGARS. They also recommended that use of a mixture of batteries would help buffer changes in the EPA regulations or future pricing changes. c. The report was reasonable in its cost evaluation for the assumptions made, but may have to be updated as the prices change with technologies improving and others being added in the future. The major drawback of the report was that it was a battery cost analysis only and some important "human" factors were not included in the study. Lithium primary batteries were used originally because of their good energy and power densities per unit weight.	

Item	Discussion	Action By
	d. A new estimate on our part by making different assumptions almost halved the cost of lithium primary and doubled the cost of the rechargeable batteries. This brought primary vs. rechargeable costs much closer together, but a cost savings still would occur if rechargeable batteries could be effectively placed into the system. e. The "manpower requirement" of using rechargeable batteries may have to weigh out against cost advantages with some type of trade-off required (hinted at in the report). This leads to logistic problems when the military is trying to get away from using mixtures of batteries. Also, the Canadian perspective for the two rechargeable batteries is different, because of the need for low temperature operation. NiCad batteries are better than lead-acid because the lead-acid must be constantly maintained and charging at low temperatures is much better for NiCad batteries. f. Question from DVEM 3 was whether the manpower cost of transporting the batteries was included in the cost estimate and that these numbers could be provided by DVEM if desired. DRDA 8-4 answered that such costs were not included, but could be added which will raise the cost of rechargeable batteries even more.	

Item	Discussion	Action By
	DASP 2-4-4 commented that he had a bit of trouble with the use of a mixture of the two battery systems in the military from a logistics and safety point of view because military batteries are fit-form-function, which raises the concern for having a lithium battery charged in a NiCd charger, the result being a disaster. DRDA 8-4 agreed this was a problem, but the report was looking at it strictly from a cost perspective in which a savings could be made by using a mixture of primary and rechargeable batteries. DRDA 8 commented that the military might have to consider in future going with a summer power source and winter power source implementation method as a cost saving measure while still filling the soldiers' needs. TCCCS expressed interest in the study since they will be purchasing 1100 battery chargers at a cost of \$20,000 each. g. A summary of the DRDA 8-4 presentation is included at Annex D. 7. <u>CRISAT PROGRAMME: TRENDS AND REQUIREMENTS (DRDA 8)</u> a. DRDA 8 described the work done by the NATO Technology Area 8 Panel: Power and Electronic Systems in relation to the Programme for Collaborative Research Into Small Arms Technology (CRISAT). b. The objective of the panel was to produce a document on the application of power supply systems for future small arms requirements. The objective has been achieved. The recent advances in electronic, electro-mechanical and power source technology make possible changes in weapon design and ergonomics. The report puts forward suggestions initially to improve present day small arms and also to assist in the design of improved future weapons.	

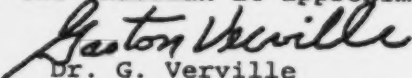
Item	Discussion	Action By
	c. In the study, the chemical cell has been identified as the most promising solution for immediate application to the CRISAT programme. In general, it is anticipated that future chemical cell power supplies will follow an evolutionary development. It is anticipated that the promising technologies currently under development, such as the advanced primary lithium batteries and the new generation of rechargeable batteries, will have the capability to meet the most stringent requirements of the CRISAT programme. Fuel cells have recently made remarkable progress and can be considered as serious candidates for some CRISAT high power and high energy density applications. d. For low power, less than 50 W, and short duration missions, batteries are the logical choice. At combinations of high power, or longer duration missions, high energy batteries, fuel cells and engine generators are potential candidates. Engine generators and fuel cells are the preferred choices for applications greater than 500 W. Specific ways and recommendation in examining the most promising technologies have been proposed. e. For high power and high density energy applications in a small size format, the only solution available to the military is the use of expensive primary batteries based on lithium sulphur dioxide or lithium thionyl chloride. At present, high operating costs limit wider use of these batteries. It has been recommended that research and development be targeted at reducing the costs of high power and high energy density primary lithium batteries.	

Item	Discussion	Action By
	f. Although rechargeable lithium batteries offer high energy densities, they have yet to matured sufficiently to be suitable for commercial and military use. Rechargeable lithium Solid Polymer Electrolyte batteries (SPEs) have been identified as a promising technology for CRISAT applications. This new technology offers the potential of future low manufacturing costs. It is environmentally benign, it avoids electrolyte leakage to damage electronic components, and can fit any casing shape. It can be used either as a rechargeable system for training or peace time exercises, or as a primary battery during emergency or wartime situations. However, at the present time, the conductivity of SPEs is very low at room temperature and its use is precluded under these environmental conditions. It has been recommended that research and development be aimed at increasing conductivity at lower temperatures through the use of plasticisers, new polymers and "Polymer-In-Salt" materials. g. Amongst the fuel cell technology, it has been identified that the polymer Electrolyte Membrane Fuel Cells (PEMFC) represent the greatest potential for miniaturization and CRISAT applications. They produce high power density at temperatures below 100°C, allowing fast start-up and immediate response to changes in the demand for power. One of the key issues associated with PEMFCs is the supply of hydrogen in a safe, cheap and lightweight package. This issue is in fact common to any fuel cell technology for portable application. It has been recommended that research and development projects on hydrogen storage/production means, including pressurized gas, liquid hydrogen, disposable and rechargeable hydrides, and miniaturized reformers be supported.	

Item	Discussion	Action By
	h. There are a number of critical battery issues which include the requirement for an indication of battery state-of-charge, the provision of fast and front line battery chargers, and the deficiencies in performance exhibited by most battery technologies operating at low temperatures. In order to make batteries an acceptable item for future service weapons the above issues must be addressed. i. A summary of the DRDA 8 presentation is included at AnnexE 8. <u>UPDATE OF CF ACTIVITIES AND REQUIREMENTS LAND</u> a. DLR 4-6 commented on land power requirements: Generator sets (>10KW and <100KW), Batteries - the army has an R&D committee to address R&D requirements. The committee is concerned with low temperature operation and safety. The capability of alkaline rechargeable batteries to replace some current batteries will be investigated. Also, they are currently monitoring the navy AIP project to assess fuel cells performance for generator set application. b. DVEM 5-4 stated that their objective was to reduce cost while still maintain customer satisfaction (customers are the battery users in CF). The O&M costs are considerable, amounting to 50% of the battery costs. Only two position left in DVEM to handle battery issues, so more to be done with less resources. c. Issue of concern is the poor state of many battery shops in the CF and the potential closure of some of them. This was seen as a potential problem when the TCCCS program comes into the picture because better battery shops will be needed.	

Item	Discussion	Action By
	d. Another issue was the CF trend of going and directly purchasing commercial batteries. There is a drive to replace MIL spec batteries by commercial ones. There are over 15 pages of replacement batteries in CF manuals. The data available can be easily misinterpreted by an uninformed user concerned only with cost saving. e. A final issue is the shelf-life of batteries. DEMPS recommends that the shelf life of batteries be extended. A proper evaluation must be made before this can be done but the problem is that DVEM does not have the resources to handle all the problems. Disposal costs are increasing and are being passed on to users. Need batteries with greater shelf life to help reduce costs. DVEM wants more technical help from the DRDA battery group. f. A "buy and try" evaluation is being done at LETE on "smart" battery chargers manufactured by ELTEX of Sweden and CADEX of B.C. Battery disposal problems for lithium primary batteries and a study of commercial types of batteries (alkaline rechargeable) are issues currently being discussed with DRDA 8-3. Several references were made to the on-going need for state of charge for batteries. <u>AIR</u> a. DRDA 8-3 gave an update on two projects involving the CF. A project dealing with the disposal of lithium batteries in which the presence of free cyanide and acetonitrile products could present a potential environmental hazard is now using a new method, HPLC, for metal-cyanide detection.	

Item	Discussion	Action By
	b. The CPI project is coming to an end with 108 final production batteries delivered, with 80 put into service, 10 qualified, and 18 kept for further evaluation. This project will help in providing a means of developing a standard. A problem with the CPI batteries is the foam package that picks up moisture at high temperatures. Also the cells are actually too large for the size of the CPI compartment because only C-size cells could be procured at the time due to the IRAQ conflict. In future, a smaller cell should be procured from Ballard and the foam packaging should be improved. For the ELT project one half D size cells at a cost of about \$50 per battery will be used. An airworthiness standard for the CPI, PLB, and ELT is required. c. A summary of the DRDA 8-3 presentation is included at Annex F. <u>NAVY</u> a. The Navy has several minor projects dealing with fuel cells technology. RMC is being used as the Navy's technical expertise and is currently evaluating a Ballard fuel cell stack and Alupower bed (both 4 KW). b. A summary of the projects sponsored by the Navy is included at Annex G. 9. <u>GENERAL DISCUSSION</u> Following the project presentations, DRDA 8 opened the floor to questions and discussion on the topics addressed at the meeting.	

Item	Discussion	Action By
	10. <u>CLOSING COMMENTS</u> DRDA 8 closed the meeting by saying that another meeting will be set up in Nov 94. Any comments by those in attendance should be sent in writing as soon as possible so that the request may be properly documented. 11. The Advisory Committee Meeting was adjourned by the chairman at approximately 13:00 Hrs.  Dr. G. Verville Chairman, R & D Advisory Committee Dr. E. Andrukaitis Secretary	DRDA 8

ANNEX A

AGENDA

DND ELECTROCHEMICAL POWER SOURCES ADVISORY COMMITTEE

CRAD conference Room
8th floor
Constitution Building
305 Rideau Street

25 November 1993

0900 HRS	<u>INTRODUCTION, REVIEW OF LAST MINUTES</u>	DRDA
0915 HRS	<u>OVERVIEW OF DND ELECTROCHEMICAL POWER SOURCES R&D</u>	DRDA8
0930 HRS	COFFEE	
0945 HRS	<u>CANADA-U.S. BATTERY SECTOR STUDY</u>	DDIR6
1015 HRS	<u>UPDATE OF CF ACTIVITIES AND REQUIREMENTS</u>	
	-LAND: DLR, DSVEM	
	-AIR : D/DGAD, DASP, DAS Eng, DMAEM	
	-MARITIME: DNR, DMEE	
1045 HRS	<u>CRISAT PROGRAMME: TRENDS IN POWER SOURCE TECHNOLOGY</u>	DRDA8
1115 HRS	<u>PRIMARY OR RECHARGEABLE BATTERIES U.S. MARINE CORPS COST ESTIMATE ON AIRBORNE RADIC SYSTEMS</u>	DRDA8-4
1145 HRS	<u>GENERAL DISCUSSION</u>	

ANNEX B



DRDA 08 PROJECT

ADVANCED ELECTROCHEMICAL

POWER SOURCE TECHNOLOGY

ELECTROCHEMICAL POWER SOURCE TECHNOLOGY

OBJECTIVES:

***DEVELOP POWER SOURCES FOR SPECIFIC DND APPLICATIONS**

***IMPROVE SHELF LIFE, SAFETY, RELIABILITY AND LOW TEMPERATURE PERFORMANCE**

FUNDING:

\$1180K ANNUALLY

PERFORMERS:

UNIVERSITIES	60%
OTHER GOV AGENCIES	30%
INDUSTRIES	10%

POWER SOURCES TECHNOLOGY

Defence Research and Development Strategic Plan

CRAD technologies:

- " Critical Component "**
- Air Vehicles
 - Marine Vehicles
 - Land Combat Engineering
 - Ordnance
 - Energetic Materials

Defence Capabilities:

- " Critical Technology "**
- Mobility
 - Minimize O&M Costs
- " Important Technology "**
- Surveillance
 - Verification
 - Communications
 - Human Protection
 - Survivability/Vulnerability
 - Firepower

DRDA 08 PROJECT

<u>WORK UNIT</u>	<u>NAME</u>	<u>92/93</u>	<u>93/94</u>
1	PRIMARY BATTERIES	41%	35%
2	ADVANCED RECHARGEABLE BATTERIES	45%	45%
3	SOLID POLYMER FUEL CELLS	14%	20%

PROGRAM ALLOCATIONS: \$ 1181 K

LITHIUM BATTERY RESEARCH

1993 GOALS AND MILESTONES

- * ESTABLISH COMPLETE CAPABILITY TO FABRICATE RELIABLE, REPRODUCIBLE LITHIUM ION BUTTON CELLS AT THE PRODUCT DEVELOPMENT LEVEL (NRC AND ELECTROFUEL)
- * CHARACTERIZE PERFORMANCE AND ANALYZE A NEW FAMILY OF SOLID POLYMERS WORKING AT 0C (IREQ)
- * COMPLETE THE STUDY OF THE REACTIVITY OF LITHIUM WITH WATER (INRS)
- * CHARACTERIZE WITH RAMAN SPECTROSCOPY THE DISCHARGED PRODUCTS OF RECHARGEABLE $\text{Li/LiAlCl}_4\text{.xSO}_2\text{/C}$ SYSTEM (U OF OTTAWA)
- * CHARACTERIZE THE EFFECT OF ELECTROLYTE COMPOSITION AND IMPURITIES ON NOISE SIGNATURES (FARRINGTON LOCKWOOD LTD)

SOLID POLYMER FUEL CELL SUPPORT

1993 GOALS AND MILESTONES

- * COMPLETE EVALUATION OF THE 5KW BALLARD MARK V FUEL CELL AND DEVELOP MATHEMATICAL MODEL (RMC)**
- * SELECT THE BEST AVAILABLE CATALYST FOR METHANOL REFORMING AND CARRY OUT LONG-DURATION PERFORMANCE TESTING (RMC)**
- * DEVELOP AN IMPROVED UNDERSTANDING AND DESIGN-ANALYSIS CAPABILITY OF CARBON MONOXIDE REMOVED IN A SELECTIVE OXIDATION REACTOR UPSTREAM OF A FUEL CELL (RMC)**
- * CHARACTERIZE THE EFFECT OF CARBON MONOXIDE POISONING ON HETEROPOLYACID CATALYSTS TO ASSESS LONG TERM PERFORMANCE (ECOLE POLYTECHNIQUE)**

FUTURE ACTIVITIES

LITHIUM PRIMARY SYSTEMS

LITHIUM RECHARGEABLE SYSTEMS:

- SOLID POLYMER BATTERY
- LITHIUM IONIC BATTERY

SOLID POLYMER FUEL CELL

*** RECOMMEND PROGRAM CONTINUE ITS PRESENT DIRECTION WITH ONLY SLIGHT CHANGE OF EMPHASIS ON ADVANCED RECHARGEABLE BATTERIES AND FUEL CELL TECHNOLOGY AS TECHNOLOGY OF NON-RECHARGEABLE BECOMES MORE ESTABLISHED**

EMERGING TECHNOLOGIES

PRELIMINARY EVALUATION AND WATCHING BRIEFS ON:

- SUPERCAPACITOR
- Zn/MnO₂ RECHARGEABLE
- NICKEL HYDRIDE RECHARGEABLE

FUTURE TRENDS

NEED FOR:

- * HIGH MOBILITY, LOW MAINTENANCE**
- * INCREASED POWER DEMAND AND PULSE POWER**
- * ARCTIC OPERATION**
- * REDUCED DETECTABILITY AND COST**
- * STATE-OF-HEALTH BATTERY MONITORING DEVICES**
- * ENVIRONMENTAL ACCEPTABILITY**

DRDA 08 PROJECT

PERFORMING SECTOR 93/94

<u>INSTITUTION</u>	<u>%</u>
CANADIAN UNIVERSITIES	53
CANADIAN NON-PROFIT INSTITUTION	29
CANADIAN FIRMS	10
ROYAL MILITARY COLLEGE	8

PROGRAM ALLOCATIONS: \$ 1181 K

ANNEX C

JOINT BATTERY SECTOR STUDY

Outline

- Background
- Objective
- Methodology
- Scope
- Final Report

Background

- DoD/DND Identified Over 30 Critical Sectors of the North American Defense Industrial Base
- Battery Sector Selected as Top Priority
 - Pervasive Multi-Service Application
 - Dual Use Potential
- A Battery Working Group was Established to Assess the Health of the Battery Industrial Base
 - Representatives from:

OASD	Marine Corps
Army	DLA
Navy	FEMA
Air Force	Canada-DND

Objective

- Conduct an industrial base assessment of the North American battery industry
- Recommend a cost effective strategy for meeting future military battery needs

Methodology

- Survey Entire Battery Base
- Identify Critical Battery Chemistries
- Select Key Contractors for Further Study
- Obtain Industry Input

11/1/83

Page 5

Scope

- Assessment of Production Capabilities
- Military/Commercial Market Relationships
- Trends in Military/Commercial R&D
- Current Business Practices
- Lessons Learned

Final Report

- Health of Sector
- Recommendations
 - Managerial Strategy
 - Business Decisions
 - Production Enhancements
 - Investment Strategies
 - Technology

Specific Areas of Concentration

- A Technical Description of the Battery Sector
 - Definition
 - Battery Components
 - Classification
 - Battery Properties
- Research and Development Activities
 - U.S./Canadian Government
 - Consortia
 - Commercial
 - Foreign
- Applications
 - Weapon Systems
 - Commercial Applications
 - Other Military Applications
- Technical Barriers
 - General Impediments
 - Technology Gaps

Specific Areas of Concentration

(Continued)

- **Market Assessment**
 - North American Battery Producers
 - End Users, Domestic and Foreign
 - Foreign Producers
- **Other Considerations**
 - Environmental
 - Recycling
 - Policy/Regulations
 - Viability/Vulnerability
- **Specific Considerations**
 - Technical Requirements (Military)
 - Future Trends (Commercial/Military)
 - Military Unique Applications
 - Trends in R&D
 - Business Climate
 - Lead Time/Reconstitution
 - Dual Use

Points of Contact for Joint Battery Sector Study

<u>POC</u>	<u>Office</u>	<u>Phone</u>
Dilip Punatar	WL/MTAP	(513) 255-3920 x250
Marc Geiter	CECOM	(908) 532-8941
Rod White	IEA	(309) 782-6967
Junius Artis	NAVSHIPSO	(215) 897-3161
Bryan Prosser	Marine Corps	(703) 640-4550
Michael Slack	DDIR	(613) 945-7107

Battery Suppliers

- Ballard Power & Research Inc.
- Moli Energy
- Alexander Mfg. Co.
- Concorde Battery Corp.
- Pro Battery West
- Sanyo Energy Corp.
- Teledyne
- Yuasa Battery (America) Inc.
- BST Systems Inc.
- Duracell Inc.
- Yardney Electric
- ACR Electronics Inc.
- Gates Energy Products
- GNB Industrial Battery Co.
- tdi Battery
- Delco/Remy - Div. of GM
- Exide Electronics
- Battery Engineering Inc.
- COMSAT Labs Inc.
- Saft America Inc.
- Ovonic Battery Co. - Div. Energy Conversion Devices
- ACME Battery Mfg. Co. Inc.
- Eagle-Picher
- Eveready
- Exide Lightguard
- Progressive Technologies Inc.
- Maxell Corp. of America
- Power Conversion Inc.

Battery Suppliers

(Continued)

- Electrochem Industries
- Gulton Industries
- Mallory, P.R. & Co.
- Tadiran Electronic Industries Inc.
- Alupower Canada Limited
- Electrofuel Mfg. Co. Ltd.
- C&D Charter Power Systems Inc.
- C and D Batteries, an Allied Co.
- East Penn Mfg.
- Exide Corp.
- Honeywell
- Marathon Manufacturing Co.
- Electric Storage Battery Co.
- Johnson Controls
- Rayovac
- Electron Dynamics Div. / Hughes Aircraft
- W. R. Grace

Battery Supplier Site Visit Ranking

SUPPLIER				BATTERY TYPES										SUPPLIER DATA			MILITARY										
Primary / Secondary Ranking				COMMERCIAL						MILITARY				BUSINESS			R & D		CUSTOMER								
BDM RANK	Company	State	Total Customers	Air Force Rank	Army Rank	Lithium	Nickel Metal Hydride	Alkaline	Nickel	Cadmium	Lead Acid	Lithium Manganese Dioxide	Thermal	Lithium Sulfur Dioxide	Lithium Ion	Lithium Thionyl Chloride	Silver Zinc	Magnesium	% Military	% Commercial	Sole Source	Ongoing R & D Efforts	Navy	Air Force	Army	Marines	Canadian DND
1	Saft America Inc.	NC	5	1	1	•			•					•		•							•	•	•	•	•
2	Ballard Power & Research Inc.	BC	3	2	3	•								•								•		•	•		•
3	Alexander Mfg. Co.	CA	3	3	8				•							•				10	90			•	•	•	
4	Eagle-Picher	MO	4	7	6	•	•		•				•			•							•	•	•	•	•
5	Gates Energy Products	FL	3	5	7				•															•	•	•	
6	Duracell Inc.	CT	3	4		•	•	•				•												•	•	•	
7	Rayovac	WI	2	9	5			•									•	•				•		•	•	•	
8	C & D Charter Power Systems Inc.	PA	2	6						•										6	94			•	•		
9	Concorde Battery Corp.	CA	3							•													•			•	•
10	Marathon Manufacturing Co.	TX	2	8					•																•		•
11	Exide Corp.	PA	2		9				•											97	3			•		•	
12	Exide Electronics	KY	3																					•	•	•	

[illegible]

SUPPLIER				BATTERY TYPES												SUPPLIER DATA			MILITARY								
BDM RANK	Company	Primary / Secondary Ranking				COMMERCIAL						MILITARY						BUSINESS	% Military	% Commercial	Sole Source	Ongoing R & D Efforts	CUSTOMER				
		State	Total Customers	Air Force Rank	Army Rank	Lithium	Nickel Metal Hydride	Alkaline	Nickel Cadmium	Lead Acid	Lithium Manganese Dioxide	Thermal	Lithium Sulfur Dioxide	Lithium Ion	Lithium Thiocyl Chloride	Silver Zinc	Magnesium						% Military	% Commercial	Sole Source	Ongoing R & D Efforts	Navy
25	Electrofuel Mfg. Co. Ltd.	ONT	1			•																				•	
26	Teledyne	CA	1						•																	•	
27	Ovonac Battery Co. - Div. Energy Conversion Devices	MI	1			•			•													•				•	
28	Acme Battery Mfg. Co. Inc.	MO	1																			•					
29	Exide Lightguard	NC	1						•													•					
30	Electrochem Industries	NY	1			•																			•		
31	Gulton Industries, Inc.	NY	1						•													•					
32	Mallory, P.R. & Co.	NY	1																			•					
33	Saft	GA	1	4					•															•			
34	Electron Dynamics Div. / Hughes Aircraft		1				•		•																		
35	Electric Storage Battery Co.	WI	1																			•				•	

SUPPLIER				BATTERY TYPES												SUPPLIER DATA				MILITARY						
Primary / Secondary Ranking				COMMERCIAL						MILITARY						BUSINESS		SS		R & D		CUSTOMER				
BDM RANK	Company	State	Total Customers	Air Force Rank	Army Rank	Lithium	Nickel Metal Hydride	Alkaline	Nickel	Cadmium	Lead Acid	Lithium Manganese Dioxide	Lithium Sulfur Dioxide	Lithium Ion	Lithium Thionyl Chloride	Silver Zinc	Magnesium	% Military	% Commercial	Sole Source	Ongoing R & D Efforts	Navy	Air Force	Army	Marines	Canadian DND
36	Alupower Canada Limited	ONT	1			•																				•
37	Sanyo Energy Corp.	CA	1			•			•			•													•	
38	GNB Industrial Battery Co.	IL	1								•							25	70			•				
39	Hydro-Quebec	QE	1																		•					•
40	C and D Batteries, an Allied Co.	PA	1								•												•			
41	COMSAT Labs Inc.	MD	1																				•			

ANNEX D

**UNITED STATES MARINE CORPS (USMC)
SINGLE CHANNEL GROUND AND AIRBORNE
RADIO SYSTEM (SINGARS) RECHARGEABLE
BATTERY TRADE-OFF STUDY**

Prepared by: Management Consulting and Research, Inc.
(MCR) Falls Church, Virginia 22041.

Sponsored by: United States Marine Corps
SINGARS Project Office
Quantico, Virginia 22134-5080.

Topic : Cost estimates of *three* batteries for the USMC
SINGARS project:

BA-5590/U Lithium Sulphur Dioxide (LiSO_2),
BB-490/U Sealed Lead-Acid, and the
BB-590/U Nickel-Cadmium (Ni-Cad)

OUTLINE

1. REASONS FOR THE STUDY
 2. ASSUMPTIONS MADE IN THE REPORT
 3. PRICE STRUCTURE AND CONCLUSIONS
MADE
 4. OUR COMMENTS ON REPORT
 5. OTHER WORK ON PRICE COMPARISONS
 6. SUMMARY (FACTORS IN BATTERY COST)
-

BACKGROUND

- in '75 the Army initiated development of a new combat radio which used Slow Frequency Hopping (SFH) to replace deficient radios.
- MCR in earlier reports provided complete Life Cycle Cost (LCC) estimates for SINCGARS
- About 56% (\$185 million) of the total Operations and Support (O&S) cost of \$329 million is associated with the procurement of the disposable batteries required for the manpack and the "vehicular dismountable" radios.
- Want to identify and analyze if money could be saved by utilizing rechargeable battery technology.
- If the adoption of Department of Defense Directive (DODD) 500.4 occurs, then the disposal phase is an important issue and must be anticipated.

ASSUMPTIONS MADE IN THE STUDY

A. Batteries

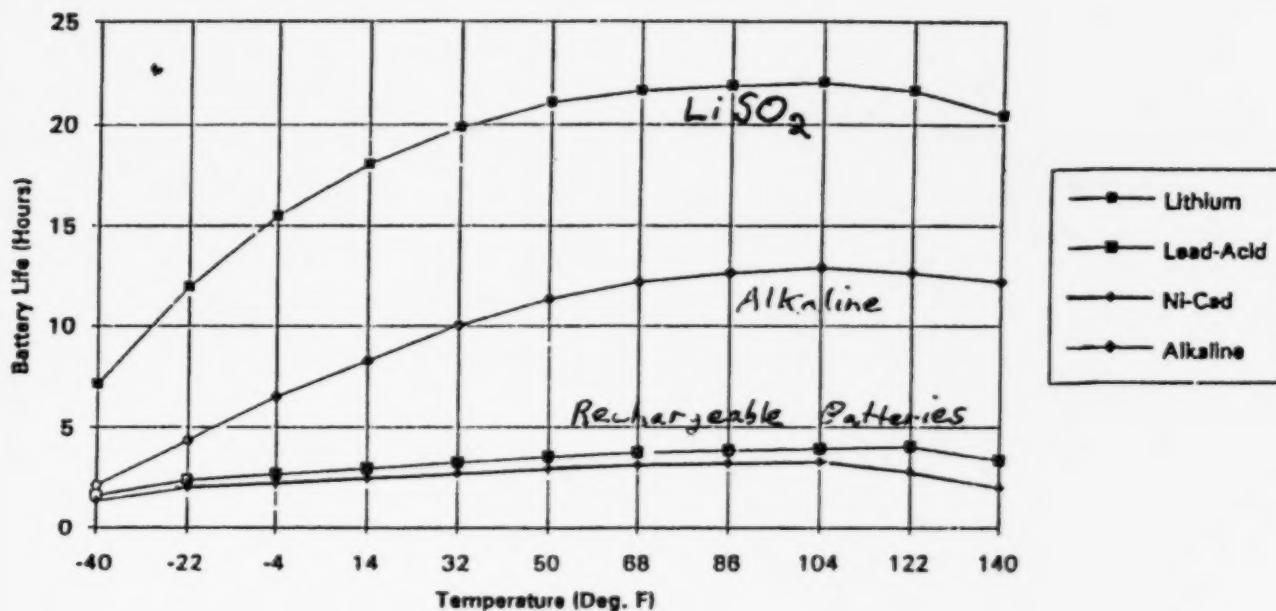
- at the time only three suitable batteries were available for SINCGARS: BA-5590/U Lithium Sulphur Dioxide, BB-490/U Sealed Lead-Acid, and the BB-590/U Nickel-Cadmium (Ni-Cad).

Others:

- Nickel Metal Hydride (although viable in future) not commercially available at the time of the study.
- Alkaline non-rechargeable batteries not compatible with application (loss of energy density with T).

B. Usage (Hours/Radio type)

- Radios are distributed 75% to active duty forces and 25% to the reserves
- Portable: 500 hrs/yr for active forces - 125 hrs/yr reserve
Vehicular: 1,000 hrs/yr active forces - 250 hrs/yr reserve
 - use battery power 10% of time
- The battery chargers are replaced when battery replaced (one charger for each radio)(vehicular radios-no charger)

AN/PRC-119 Operational Hours (Estimated)AN/PRC-119 OPERATIONAL HOURS (ESTIMATED)

- battery operational hours for a single cycle were estimated by MCR using AN/PRC-119 radio
- the lithium primary was estimated to deliver 22 hrs at ambient temperatures (5 times longer compared to the rechargeable batteries).
- alkaline battery was not considered although the performance between LiSO₂ and rechargeable batteries

C. Disposal Costs

- Transportation and waste treatment in accordance with federal / Environmental Protection Agency (EPA) regulations.
- Disposal quantity is identical to the battery replacement quantity.
- For rechargeable batteries:
 - one battery in radio and one in charger (2 batteries/radio)(always provides a useable battery)
 - radio set used for battery life estimate was the AN/PRC-119 (an overwhelming majority of the battery powered operational requirement)

PRICE STRUCTURE

- looked at four basic costs:
 1. Cost of battery itself
 2. Charger cost (recharg. only)
 3. Disposal transport
 4. Waste Treatment

TABLE 1. SUMMARY OF VARIOUS COSTS ASSOCIATED WITH THREE BATTERIES BA-5590, BB-590 and BB-490

	BA-5590/U LiSO ₂	BB-590 NiCad	BB-490 Pb-acid
Cost / Battery	\$ 45.00	\$ 164.18	\$ 225.00
Hrs of Use (cycle)	22 hrs (33 claimed)	4 hrs (6 claimed)	4 hr (see BB-590)
No. cycles	not applicable	250-500 cycles	+400 cycles
Float life (no. cycles / yr)	not applicable	213 cycles/4y float 63 cycles/yr	213 cycles/4y float 63 cycles/yr
Annual cost	\$ 9.5 million	\$ 0.9 million	\$ 1.2 million
Charger cost	not applicable	\$ 0.6 million (\$ 245/charger)	\$ 0.1 million (\$ 54/charger)
Disposal Cost / yr	\$ 2.9 million (\$6.00/lb)	\$ 55,000 (\$2.45/lb)	\$ 12,000 (\$0.60/lb)
Total Annual Cost	\$ 12.4 million	\$ 1.6 million	\$ 1.4 million
Operational Cost / hr *	<u>\$ 2.66</u>	<u>\$ 0.34</u>	<u>\$ 0.30</u>

* Report uses 4.7 million operational hours per year for radios

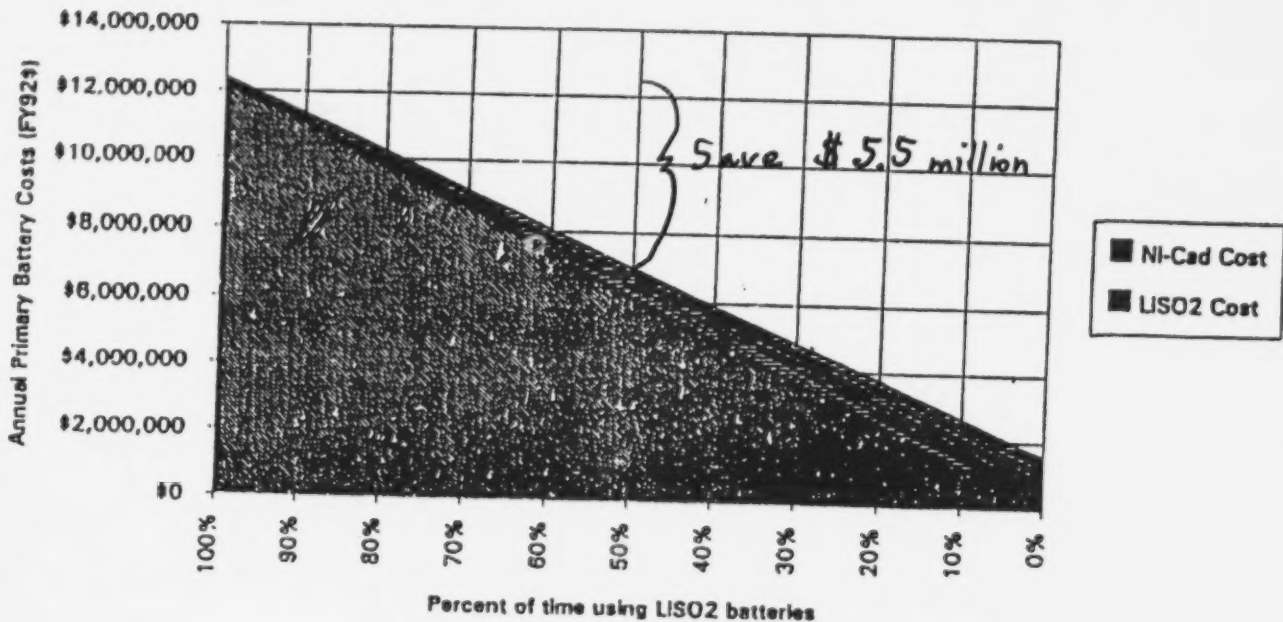
CONCLUSIONS OF STUDY

- The two rechargeable batteries for SINCGARS radios are significantly less costly / hr than LiSO_2 (1 LiSO_2 = 5 rechargeable batteries)
- Pb-acid slightly preferable to NiCad for SINCGARS:
 - cheaper on a life cycle cost basis
 - simpler and more rugged than NiCad
 - slightly better discharge characteristics
 - rechargers cheaper and broader choice
 - easier to recycle (many recyclers around)
- NiCad and Pb-acid technology is improving wrt cycle life, float life and to a lesser extent energy density.
- Nickel Metal Hydride may soon be commercially available (better performance wrt energy density
 - easier disposal).

TRADE-OFF ANALYSIS

- looked at cost savings if a mixture of LiSO_2 and rechargeable batteries was used with two scenarios:
 - a) LiSO_2 with NiCad OR b) LiSO_2 with Pb-acid

USMC SINGARS Annual Primary Battery Cost (LISO2 - Ni-Cad Mix)



USMC SINGARS ANNUAL PRIMARY BATTERY COST (LISO2-NICAD MIX)

- Example: 50:50 mixture of a) would have cost of \$ 7 million / yr for a saving of \$ 5.4 million (\$ 5.5 million for case b))
- use of a mixture would help to buffer changes in EPA regulations or any pricing changes.

CRITIQUE OF REPORT

Overall: Was reasonable for assumptions they made at the time, however, may have to update soon, for several reasons:

- the price structure changes as certain technologies improve
- new (cheaper ?) alternatives within next 5 yrs
(ex. Ni metal-hydrides, rechargeable alkaline batteries, high energy density Pb-acid foil technology).
- Was a battery cost analysis ONLY: Some important factors not included in study were "human" factors.
 - Manpower requirements increase with rechargeables.
 - Impact of changing battery on equipment and user important in operational requirements.
 - Problems with rechargeable batteries for active forces.
(weight consideration - comment made "AN/PRC-119 radio will be operated in excess of approximately 110 hours without resupply, the total weight of the lithium batteries is in excess of the total weight of lead-acid batteries (including recharger)". (LiSO₂ weighs 2.2 lbs. - Pb acid weighs 3.5 lbs.)

OTHER STUDIES

Business Opportunities for Portable Batteries (1988 vol. II).

- Studied U.S. Military portable battery market
- U.S. Army LABCOM plans to standardize its battery packs in terms of voltage and battery technology (use of lithium rechargeables seen as probable lead up to a "universal battery" in late 90's).
- From a performance standpoint: Li batteries are a lower cost for higher discharge applications (above 0.5 A) (most Army's new equipment operates above this / D cell).

Article in ELECTRONICS PURCHASING (Aug. 93)

- NiCad has cost / watt hour of \$ 0.75 - \$ 1.50 and 1,000 full discharges
- Pb-acid costs \$ 0.25 - \$ 0.75 up to 2,000 cycles (discharge rate 1-3% per month, NiCad 10-20% / month) ex. 18 Wh laptop NiCd \$25, NiMH cost \$42 and Pb-acid \$12 (wt. 16 ounces to 13 for NiCd and 14 for NiMH).
- Valence Technology to deliver Li SPE rechargeable with 4x capacity of Ni-Cd (price between Ni-Cd and Ni-Mh)

OUR ADDED INPUT TO COST ESTIMATES

- Several "alterations" may make difference between primary and rechargeable not as slanted as in report
- ASSUMPTION 1 - 22 hr. discharge of LiSO₂ battery may be severe for a primary battery
 - Use 30 hr. discharge time
- ASSUMPTION 2 - G.D. in speaking with US military only 10% of all Li batteries are actually being "officially" disposed
- ASSUMPTION 3 - "manpower cost" which includes time taken by personal to recharge the batteries
- ASSUMPTION 4 - logistics of rechargeable batteries on man and radio ("user friendly" for active forces?)

TABLE 2. COST - ADDING "OUR" ESTIMATES FOR THREE BATTERIES BA-5590, BB-590 and BB-490

	BA-5590/U LiSO ₂	BB-590 NiCad	BB-490 Pb-acid
Cost / Battery	\$ 45.00	\$ 164.18	\$ 225.00
Hrs of Use (cycle)	30 hr (33 claimed) [# 1]	4 hrs (6 claimed)	4 hr (see BB-590)
No. cycles	not applicable	250-500 cycles	+400 cycles
Float life (no. cycles / yr)	not applicable	213 cycles/4y float 63 cycles/yr	213 cycles/4y float 63 cycles/yr
Annual cost	\$ 7.0 million [# 1]	\$ 0.9 million	\$ 1.2 million
Charger cost	not applicable	\$ 0.6 million (\$ 245/charger)	\$ 0.1 million (\$ 54/charger)
Disposal Cost / yr	[# 2] \$ 0.3 million (\$6.00/lb)	\$ 5,000 (\$2.45/lb)	\$ 1,000 (\$0.60/lb)
Additional "Manpower Cost"	not applicable	\$ 0.6 million [# 3] (others ??)	\$ 0.6 million [# 3] (others ??)
"Logistics Cost"	not applicable	\$ 0.2 million [# 4]	\$ 0.2 million [# 4]
Total Annual Cost	\$ 7.3 million	\$ 2.4 million	\$ 2.2 million
Operational Cost / hr *	<u>\$ 1.55</u>	<u>\$ 0.52</u>	<u>\$ 0.47</u>

* Using 4.7 million operational hours per year

CONCLUSIONS

Lots of factors can alter overall acceptance of a battery:

- Performance requirement, safety and reliability.

- Overall, from pure cost perspective the report was well done with the claims valid for the assumptions made giving secondary batteries a large cost savings compared to LiSO_2 .
- Assumptions gave reasonable cost comparison, (may vary with time -arrival of newer (cheaper?) technologies

- "Manpower requirement" of using rechargeable battery may have to weigh out against cost advantages (trade-off required - hinted in report by keeping a mixture).

- New technologies (NiMH and rechargeable alkaline) and steady improvement to old ones (Pb-acid and Ni-Cd) make for an interesting (if not more complicated) situation for LCM's in the future trying to sort out what's what for their power source needs. (N.B. A mfg. Co. will always say their batteries are the best!!)

CANADIAN Perspective is DIFFERENT !!

- Temperature problem with rechargeable batteries
- NiCad is better than lead-acid:
 - lead-acid must be constantly maintained
 - charging at low temp. better for NiCad

FOR COPY OF REPORT

- Can be obtained from DSIS - Report no. TR-92214/01

**Title: UNITED STATES MARINE CORPS (USMC) SINGLE
CHANNEL GROUND AIRBORNE RADIO SYSTEM
(SINGARS) RECHARGEABLE BATTERY
TRADE-OFF STUDY**

**Prepared by: Management Consulting and Research, Inc.
(MCR) Falls Church, Virginia 22041.**

**Sponsored by: United States Marine Corps
SINGARS Project Office
Quantico, Virginia 22134-5080.**

ANNEX E

NATO ARMY ARMAMENTS GROUP
PANEL III ON CLOSE COMBAT - INFANTRY
SUB-PANEL 5 ON NATO SMALL ARMS POST 2000

Program for Collaborative Research Into Small Arms Technology (CRISAT)

Technology Area 8 (TA8): Power and Electronic Systems

FINAL REPORT
September 30, 1993

OBJECTIVE

- i) Produce a panel document on the application of electronics to future small arms requirements, and investigate improvements to reliability, performance and cost effectiveness.
- ii) Produce a panel document on the application of power supply systems for future small arms requirements.

WEAPON TYPES

NATO D/296

PERSONAL DEFENCE WEAPON (PDW)	0.7 Kg
INDIVIDUAL COMBAT WEAPON (ICW)	4.5 Kg
SUPPORT WEAPON (SW)	10-20 Kg

Lithium Primary Batteries

For high power and high density energy applications in a small size format, the only solution available to the military is the use of expensive primary batteries such as lithium-sulphur dioxide or lithium thionyl chloride cells. At present, high operating costs limit wider use of these batteries.

Recommendation

It is recommended that research and development be targeted at reducing the costs of high power and high energy density primary lithium batteries.

Lithium Rechargeable Systems

Although rechargeable lithium batteries offer high energy densities, they have yet to matured sufficiently to be suitable for commercial and military use. Rechargeable lithium Solid Polymer Electrolyte batteries (SPEs) have been identified as a promising technology for CRISAT applications. This new technology offers the potential of future low manufacturing costs. It is environmentally benign, it avoids electrolyte leakage to damage electronic components, and can fit any casing shape. It can be used either as a rechargeable system for training or peace time exercises, or as a primary battery in an emergency or wartime situations. However, at the present time, the conductivity of SPEs is very low at room temperature and its use is precluded under these environmental conditions.

Recommendation

It is recommended that research and development be aimed at increasing conductivity at lower temperatures through the use of plasticisers, new polymers and "Polymer-In-Salt" materials.

Polymer Electrolyte Membrane Fuel Cells

PEMFC represent the greatest potential for miniaturization and CRISAT applications. They produce high power density at temperatures below 100°C, allowing fast start-up and immediate response to changes in the demand for power.

One of the key issues associated with PEMFC is the supply of hydrogen in a safe, cheap and lightweight package. This issue is in fact common to any fuel cell technology for portable application.

Recommendation

It is recommended that research and development projects on hydrogen storage/production means, including pressurized gas, liquid hydrogen, disposable and rechargeable hydrides, and miniaturized reformers be supported.

Critical Batteries Issues

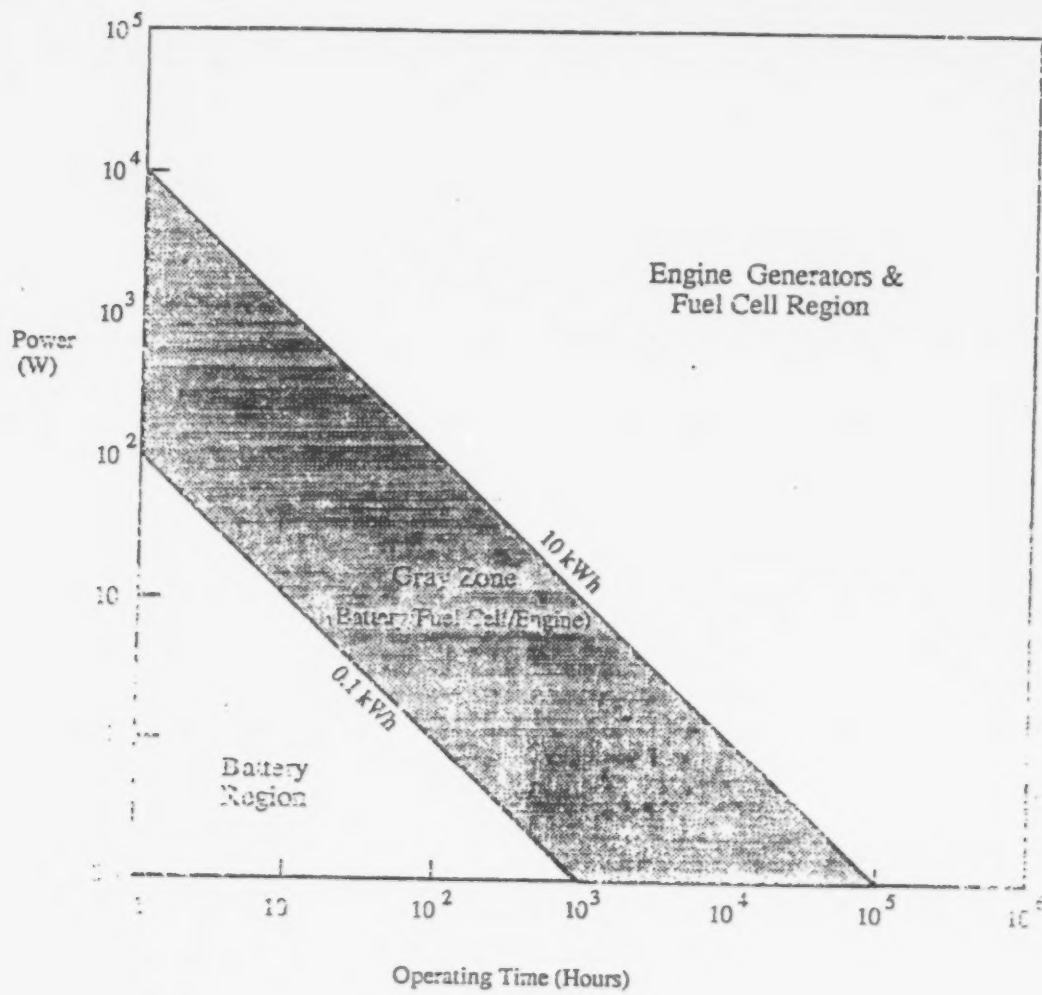
State-of-Charge of Batteries

Fast and Front Line Smart Chargers

Deficient Low Temperature Operation

Table 5-1
Potential Application of Power Supply Systems

Technology	PDW	ICW		SW	
		Conventional	SAWS	Conventional	SAWS
Prime Movers					
1. Liquid Fuel Engines/ Turbines	No	No	Possible	Possible	Possible
2. Gas Fuel Engines/ Turbines	No	No	No	No	No
3. Compressed Gas Motors	No	No	No	No	No
4. Chemically Fuelled Motors	No	No	No	No	No
Generators					
5. Alternating Current	No	Possible	Possible	Possible	Possible
6. Direct Current	No	Possible	Possible	Possible	Possible
7. Magnetohydrodynamics	No	No	No	No	No
Chemical Cells					
8. Primary	Yes	Yes	Yes	Yes	Yes
9. Rechargeable	Yes	Yes	Yes	Yes	Yes
10. Fuel Cells	No	Possible	Possible	Yes	Yes
Other Static Sources					
11. Nuclear	No	No	Possible	Possible	Possible
12. Solar	No	No	Possible	Possible	Possible
Rechargeable Supplies					
13. Wind Driven Generators	No	No	No	No	No
14. Water Driven Generators	No	No	No	No	No
Miscellaneous					
15. Thermoelectric Technology	No	No	No	Possible	Possible
16. Human	No	No	No	No	No



Graph 5-1

Table 5-2 Properties of Selected Non-Rechargeable, Portable Batteries.

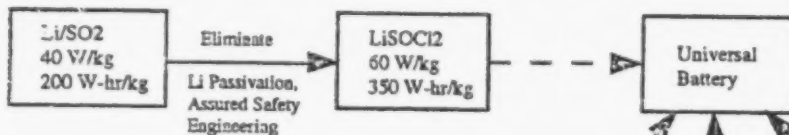
Cell Couple	Open circuit voltage (V)	Nominal * load voltage (V)	Practical Energy Density		Power density (W kg ⁻¹)**
			By weight (Wh kg ⁻¹)	By volume (Wh dm ⁻³)	
Zinc/manganese dioxide (alkaline)	1.5	1.25	125	320	7 (D, 0.6A)
Lithium/sulphur dioxide	2.9	2.75	250	400	60 (D, 2A)
Lithium/polycarbon monofluoride	3.0	2.8	360	680	14 (C, 0.3A)
Lithium/vanadium pentoxide	3.4	3.3, 2.4	120, 260	300, 660	11 (1.5" button, low rate)
Lithium/manganese dioxide	3.4	2.8	280	580	50 (D, 2A)
Lithium/thionyl chloride	3.65	3.5	290	670	105 (D, 4A)
Lithium/thionyl chloride and bromine chloride	3.9	3.7 to 3.5	350	770	75 (D, 3A)
Lithium/sulphuryl chloride	3.95	3.7	330	720	100 (D, 4A)

Table 5-3 Performance, Advantages and Disadvantages of Selected Secondary Cells

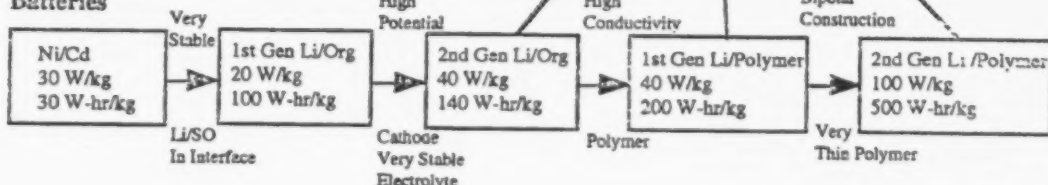
Cell Type	Voltage V	Cycles	Energy Density Wh/kg	Density Wh/l	Peak Power W/kg (1sec. discharge)	Advantages	Disadvantages
Pb/PbO ₂	1.95	650-800	52.	120.	435.	well known excellent power cheap	low energy density, D-cell smallest size
Ni/Cd	1.25	3000	60.	120.	210.	well known excellent power use in battery packs	energy density memory effect Cd is toxic
Zn/MnO ₂	1.25	55	60.	130.	n/a	well known, very cheap.	corrosion of Zn
Zn/AgO	1.70	50-150	120.	240.	400.	high energy density good shelf life	cost low cycle life
Li/V ₆ O ₁₃	3.0	40.	100.	180.	n/a	insoluble in organic solvents	low power sloping voltage
Li/MnO ₂	2.8	400-1000	125.	240.	200.	higher voltage low power	costly
SPE Li/VO _x	3.0	1000	93.	115.	n/a	good shelf life, low toxicity safety, flexibility	costly poor power poor at <25 °C
Ni/Zn	1.6	400	70.	130.	260.	non-toxic high energy density	low cycle life cost
Ni/MH	1.25	1000	80.	240.	n/a	high cycle life excellent power capability, reliable	poor shelf life expensive

ADVANCES IN ELECTROCHEMICAL POWER SOURCES

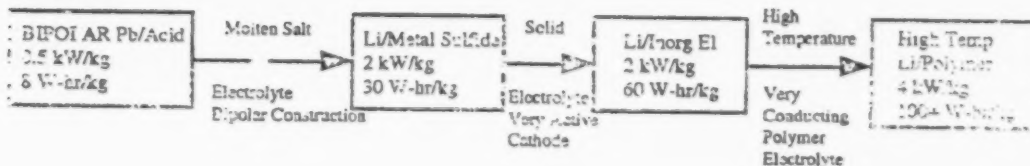
Primary Batteries



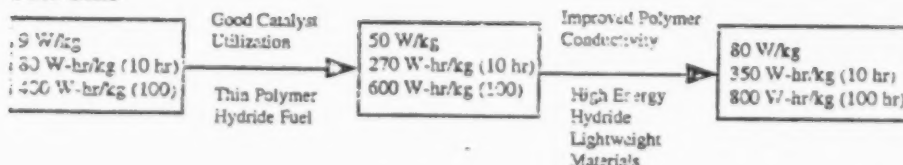
Rechargeable Batteries



Pulse Power Batteries



Solid Polymer Electrolyte Fuel Cells



Now

2-10 Years

Beyond CRISA T

Figure 5-5

Universal Battery Concept

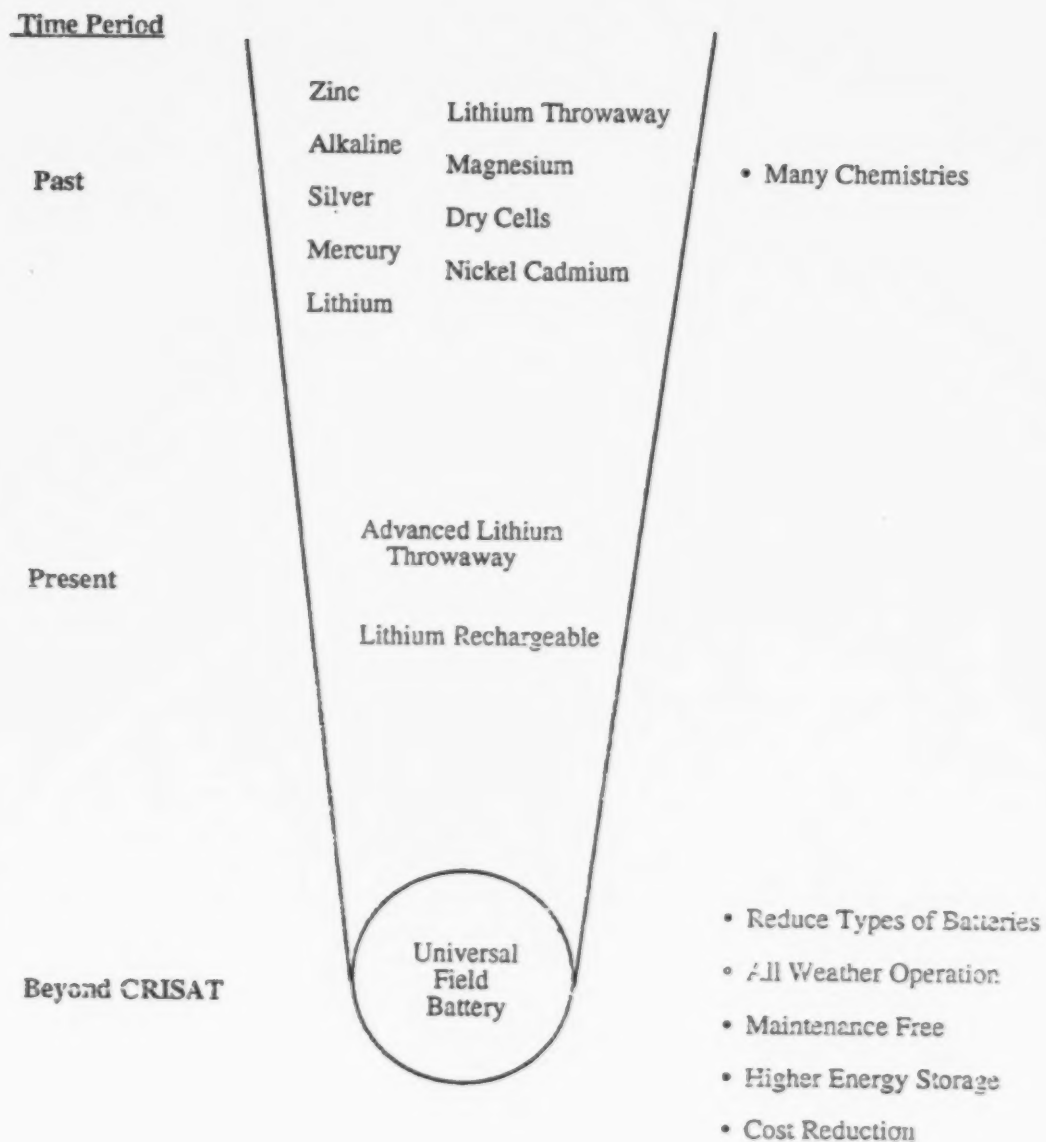


Figure 5-2

Table 7-3
Power Supply for SW
Combat Mission

Mission Scenario:

The weapon is operated in a suppression mode in support of advancing troops.
Data is presented for 24 hour mission.

Equipment	Usage Rate	Watts	Watt-Hours (24 hr)
Microprocessor operating	1.0	0.1	2.4
Initiator	(10000 rounds)	1.5	0.4
Enhanced Vision (thermal)	1.0	8.0	192.
Weapon Cycling	0.02	240.	115.
Range Finder	0.01	10.0	2.4

Note: a. Weapon weight = 10 Kg
b. Battery weight = 1.0 Kg

Summary:

Peak Power = 260 W
Average Power = 8 W
Energy = 312 Wh

Power Density = 260 W/Kg
Energy Density = 312 Wh/Kg

Table 7-1
Power Supply for the PDW
Combat Mission

Mission Scenario:

A soldier is in a defense mode. His weapon is drawn from his holster. The weapon is in the ready mode for a duration of at least 24 hours.

Equipment	Usage Rate	Watts	Watt-Hours (24 hr)
Microprocessor			
standby	0.95	10×10^{-6}	2×10^{-4}
operating	0.05	50×10^{-6}	6×10^{-5}
Initiator	(200 rounds)	1.5	8×10^{-5}
Laser Designator	0.05	0.5	0.6

Note: a. Weapon weight = 0.7 Kg
b. Battery weight = .07 Kg

Summary:

Peak Power = 2 W
Average Power = 10×10^{-6} W
Energy = 0.6 Wh

Power Density = 29 W/Kg
Energy Density = 7 Wh/Kg

Table 7-2
Power Supply for ICW
Combat Mission

Mission Scenario:

A soldier is in an offensive posture for 20% of the time and 80% of the time in the defensive posture. His weapon is in the ready mode. Data is presented for a 24 hour mission.

Equipment	Usage Rate	Watts	Watt-Hours (24 hr)
Microprocessor operating	1.0	0.1	2.4
Initiator	(1000 rounds)	1.5	4×10^{-2}
Enhanced Vision (thermal)	1.0	4.0	96.
Range Finder	.001	10.0	0.2

Note: a. Weapon weight = 4.5 Kg
b. Battery weight = 0.45 Kg

Summary:

Peak Power = 15.6 W
Average Power = 4.1 W
Energy = 100 Wh

Power Density = 35 W/Kg
Energy Density = 222 Wh/Kg

ANNEX F

ACETONITRILE-CYANIDE RESEARCH

OBJECTIVES

- 1 Develop reliable methods for
free cyanide
AN products
- 2 Investigate conditions for decomposition of AN
- 3 Evaluate environmental hazard

CYANIDE ANALYSIS

SPECTROSCOPIC

Interference from AN, S₂O₄, BrO₃
and Amines from AN decomp.

ION CHROMATOGRAPHY

Interference from large amounts of Br
Detection limit 100 mg in D cell

NEW METHOD

I. C. for free CN and SCN
HPLC for metal-cyanides

Detection limit 1 mg for D cell

Interference: sulphide >10-fold excess
Al grid from cathode

INVESTIGATE ACETONITRILE DECOMPOSITION

CONDITIONS:

Discharge: rate, temp, extent, age

Storage: temp, duration

Sequence of events

STATUS

Amendment in progress

Phases I and II finished

Paper given at Battery Waste Management Symp

Tech Paper for Spring EPS

Contract to end 30 June 1994

Cash Phasing	92/93	93/94	94/95	
	122K	183K	10K	315K

CPI BATTERIES

108 FINAL PRODUCTION	10 FOR QUALIFICATION 80 IN SERVICE NOV 93 18 KEEP FOR STUDY
----------------------	---

QUALIFICATION	COMPLETE - LIMITED SUCCESS T-SHOCK & MOISTURE - FOAM DETERIORATED MOISTURE - 1 FAILURE
---------------	--

FUTURE	NEED SMALLER CELL IMPROVE FOAM PACKAGE RFP SPRING 94
--------	--

ELT BATTERY	300 NEEDED CELL SIZE 1/2 D RFP SPRING 94
-------------	--

AIRWORTHINESS STANDARD

COMBINE CPI, PLB, ELT REQUIREMENTS
PASS TECHNICAL INFO TO DEMPS(?) FOR ACTION

ANNEX G

**PRESENT CRAD SPONORED NAVAL FUEL CELL
DEVELOPMENT PROJECTS**

No.	NAME	AIM	FUNDING LEVEL
1.	Ballard AIP Feasibility Study *	To perform a study that will lead to a development program on solid polymer fuel cells for integration into the propulsion system of a diesel electric submarine	\$240K
2.	Alupower AIP Feasibility Study *	Same as No. 1 only based on Aluminum based semi-fuel cell	\$240K
3.	4 KW fuel cell Deval	To evaluate the operational characteristics of the Ballard 4KW SPFC	\$100K
4.	Alupower ROV XDM	Build an XDM AL/Pb acid battery hybrid system for an ROV	\$800K

5.	AIP Project Definition Studies	Project definition phase for a future major AIP dev. project D61XR	\$975K
6.	Joint DND/NASA RFC Program	Develop Regenerative Fuel Cell (RFC) exploratory development model	\$350K
7.	Alternative Fuel Program	Development of Reformers able to handle logistic fuel such as kerosene	\$975K
8.	Chemical Hydride Program	Development of a chemical hydride hydrogen generator as a fuel source for UAVs	\$200K
9.	AIP XDM	Develop two 40kw XDM energy conversion systems using SPFC and Al/O ₂ semi-fuel cell technologies	\$9,789K
		TOTAL	\$13,669K



